PROBABILITY STUDIES OF HYDROLOGIC EVENTS AND THEIR APPLICATION TO HYDRAULIC DESIGN

BY

VEN TE CHOW

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M.S., The Pennsylvania State College, 1948

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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PROBABILITY STUDIES OF HYDROLOGIC EVENTS AND THEIR APPLICATION TO HYDRAULIC DESIGN

There are many hydraulic engineering structures and projects which involve the control, or disposition, or utilization of surface- or ground-water on its course through the hydrologic cycle. The fundamental hydrologic data determine the frequency and magnitude of hydrologic events for which these hydraulic works are designed. The frequency and magnitude are called the hydrologic design values.

The main purpose of this thesis was to develop a probability study of the hydrologic design value. This involved five parts: 1. to review other methods for the determination of the hydrologic design value; 2. to introduce the methods of statistics and their applications to the field of hydrology; 3. to develop a new probability method for the frequency analysis of hydrologic data; 4. to establish the criteria for the economic analysis of hydraulic designs; and 5. to set up the procedures of the probability study of hydrologic design values.

The complete solution of an engineering problem may be divided, in general, into four important steps: 1. the determination of the design value; 2. the design of the proposed structure; 3. the construction of the designed project; and 4. the maintenance of the constructed works. It often happens that the first step is the most difficult, because, in addition to a pertinent technical knowledge, it requires an advanced type of engineering judgment and experience. The determination of design values, such as the live load of a bridge, the capacity of a water supply system, the maximum discharge over a spillway, etc. is usually a problem of such type that its solution cannot be definitely and mathematically determined. The ultimate decision must be based on broad experience and sound judgment. Nevertheless, the engineer who faces such problem should take advantage of any legitimate means to assist his judgment. The probability study presented in this thesis provides a means to meet this need in determining the influence of hydrologic events.

The probability study of hydrologic design value essentially consists of two steps; namely, the frequency analysis and the economic analysis. In developing the method of frequency analysis, existing statistical methods of hydrologic frequency analysis were thoroughly reviewed. The one developed in this study is based upon the theory

of probability, hence, it is mathematically sound. By this theory a simple relation between the characteristics of hydrologic data and the frequency of occurrence is developed as follows:

$$\frac{y}{\bar{y}} = 1 + KC_v$$

in which, y is the magnitude of largest hydrologic events which occurred in the equal time intervals of past observation; $\bar{y}$, the mean of y; C_v, the coefficient of variation of the hydrologic data; and K, the frequency factor depending on the recurrence interval of hydrologic events. The procedure of frequency analysis based on the above relation is simple and practicable, and is a useful and workable tool for hydraulic design. Numerical examples are given to illustrate the use of this method.

Regarding the economic phase of the study, the hydraulic projects and their component parts are grouped into two classes: 1. those in which safety of human life and property is paramount, and 2. those in which safety of human life and property is not paramount and the design of which must be made on a basis of most economic conditions. For the first class, a criterion is given to judge the economical justification of a proposed hydrologic design value. The criterion states that an economically justifiable hydrologic design value is such that the corresponding design would result in a benefit-cost ratio greater than unity for a given hydraulic structure or project. For the second class, two criteria are given to determine the most economical hydrologic design value. One criterion states that a most economical hydrologic design value is such that the corresponding design would result in a least total annual expenditure for a given hydraulic structure or project. The other criterion states that a most economical hydrologic design value is such that the corresponding design would result in a greatest benefit-cost ratio for a given hydraulic structure or project. The conditions, procedures, and examples for the application of these criteria are given.

In concluding the thesis, the reliability of the probability study is discussed. It is also mentioned that the results obtained by the probability study are directly applicable to practical cases. However, the final decision as to their actual uses may be subject to modifications beyond the scope of the thesis, such as those established by law, or by the basic policies of the designing agency, or by other social, financial and political factors.

VITA

Ven Te Chow was born on August 14, 1919, in Hangchow, Chekiang, China. His education, experience, writings, and memberships of societies are listed as follows:

Education

Upon graduation from the Fuh Tan High School, Shanghai, China in 1936, he entered the National Chiao Tung University and received the degree of Bachelor of Science in Civil Engineering, with honors, in June 1940. He began his graduate work at the Graduate School of the Pennsylvania State College, major in structural engineering, in September 1947, and received the degree of Master of Science in Civil Engineering in September 1948. At that time he entered the Graduate College of the University of Illinois to continue his graduate work, major in hydraulic engineering.

Experience

September 1940 to June 1941, Instructor, Section of Professional Engineering, The Great China School, Shanghai, China, teaching engineering drawing, engineering mathematics, applied mechanics, strength of materials, reinforced concrete constructions and theory of structures.

September 1941 to July 1944, Instructor, part-time, Fuh Tan School, Shanghai, China, teaching trigonometry, solid geometry, higher algebra, analytic geometry and physics.

September 1941 to July 1943, Instructor, Civil Engineering Department, Tai Tung University (Universitato Utopio), Shanghai, China, teaching descriptive geometry and applied mechanics.

September 1943 to July 1945, Assistant Professor, Textile Engineering Department, The China Agricultural and Textile Engineering College, Shanghai, China, teaching applied mechanics, strength of materials and industrial building planning.

December 1945 to October 1946, Civil Engineer, Bureau of Public Works, Formosa, China, conducting reconstruction and maintenance works on highways and highway bridges.

September 1945 to July 1947, Assistant Professor, Department of Civil Engineering, The National Chiao Tung University, Shanghai, China, teaching strength of materials, hydraulics, materials of construction, materials testing, also researching on testing of Portland cement, quartz standard sand and burnt clay. From December 1945 to October 1946 he was on leave of absence to Formosa.

September 1947 to July 1948, Research Assistant, Engineering Experiment Station, The Pennsylvania State College, working on hydraulic engineering researches: design and erection of oil pumping system using rotameter for measuring rate of flow, testing a 4-in. diameter Pelton Water Wheel manufactured by Fitz Water Wheel Co. and design of its prony brake, testing on model of 48-in. water tunnel, and testing of 50-ft.x7-in.x10-in. timber open flume.

September 1948 to July 1949, Special Research Assistant, Engineering Experiment Station, University of Illinois, researching on Hydrologic Study, Cooperative Research of Highway Drainage in connection with the design of Congress Superhighway of Chicago. The project was undertaken by the University of Illinois at the request of the State of Illinios, Division of Highways and the Public Roads Administration.

Writings (*In Chinese)

(A) Theses, Books and Reports:

B.S. Thesis—"Analysis of Rigid Frame Bridges"*, The National Chiao Tung University, Shanghai, China, June 1940.

"Analysis of Continuous Frames", 30pp., mimeographed and privately published, 1942.

"Theory of Structures"*, The World Book Co., Shanghai, China, 363pp., 1943.

"Applied Hydraulics"*, Section A-8, 90pp., Vol. A, Handbook of Engineering Fundamentals, Chinese Engineers' Handbook, The Commercial Press, Shanghai, China, 1946.

"Materials Testing"*, Section B-2, 92pp., Vol. B, Handbook of Civil Engineering, Chinese Engineers' Handbook, The Commercial Press, Shanghai, China, 1946.

"Tunneling"*, Section B-11, 196pp., Vol. B, Handbook of Civil Engineering, Chinese Engineers' Handbook, The Commercial Press, Shanghai, China, 1946.

"A Visit to Formosa", *The China Science Corporation, Shanghai, China, 248pp., 1947.

"Plane Trigonometry",* Translation, The China Science Corporation, Shanghai, China, 290pp., 1947.

Report—"Report on Flume Test", Hydraulics Laboratory, The Pennsylvania State College, unpublished, 1948.

M.S. Thesis—"Analysis of Continuous Frames by the Method of Conjugate Frames", The Pennsylvania State College, 1948.

Report—"A Study of Gumbel's Method for Flood Estimations", Hydrologic Study, Preliminary Report No. 1, Cooperative Research of Highway Drainage, University of Illinois, mimeographed, 20pp., September 1948.

Report—"A Statistical Analysis of Rainfall Data at City of Chicago by the Gumbel's Method", Hydrologic Study, Preliminary Report No. 2, Cooperative Research of Highway Drainage, University of Illinois, mimeographed, 43pp., November 1948.

Report—"An Analysis of Rainfall Data at City of Chicago by the Per Cent of Time Method", Hydrologic Study, Preliminary Report No. 3, Cooperative Research of Highway Drainage, University of Illinois, mimeographed, 27pp., January 1949.

Report—"Analysis of Rainfall Data at City of Chicago by the Partial Duration Series Method", Hydrologic Study, Preliminary Report No. 4, Cooperative Research of Highway Drainage, University of Illinois, mimeographed, 25pp., March 1949.

Report—"A Discussion of the Previous Studies on Hydrologic Analysis of Chicago's Excessive Precipitation Data", Hydrologic Study, Preliminary Report No. 5, Cooperative Research of Highway Drainage, University of Illinois, mimeographed, 19pp., July 1949.

Report—"Analysis of Excessive Precipitation Data at City of Chicago by the Modified Partial Duration Series Method," Hydrologic Study, Preliminary Report No. 6, Cooperative Research of Highway Drainage, University of Illinois, mimeographed, 36pp., November 1949.

Report—"A Study on Distribution of Number of Exceedances and Its Application for Defining Plotting Positions of Hydrologic Data", Hydrologic Study, Preliminary Report No. 7, Cooperative Research of Highway Drainage, University of Illinois, 31pp., 1950.

Report—"Analysis of Chicago's Excessive Precipitation Data by the Annual Maximum Method", Hydrologic Study, Preliminary Report No. 8, Cooperative Research of Highway Drainage, University of Illinois, 24pp., 1950.

Report—"Analysis of Excessive Precipitation Data at City of Chicago by the Method of Coefficient of Variation", Hydrologic Study, Preliminary Report No. 9. Cooperative Research of Highway Drainage, University of Illinois, 9pp., 1950.

Report—"Analysis of Chicago's Excessive Precipitation Data by the Annual Exceedance Method", Hydrologic Study, Preliminary Report No. 10, Cooperative Research of Highway Drainage, University of Illinois, 19pp., 1950.

Report—"Analysis of Maximum Intensities of Precipitation Data at Seattle, Wash.", Hydrologic Study, Preliminary Report No. 11, Cooperative Research of Highway Drainage, University of Illinois, 35pp., 1950.

Report—"Analysis of Maximum Intensities of Precipitation Data at Los Angeles, Calif.," Hydrologic Study, Preliminary Report No. 12, Cooperative Research of Highway Drainage, University of Illinois, 30pp., 1950.

(B) Articles in Magazines and Periodicals:

"Bamboo and Bamboo Reinforced Concrete",* Translation, Popular Science, The China Science Corp., Vol. 9, No. 10, pp.597-599, May 1943.

"Generation of Electricity by Water Power",* Translation, Popular Science, The China Science Corp., Vol. 10, No. 3, pp.119-121, October 1943.

"Mirage",* Popular Science, The China Science Corp., Vol. 10, No. 9, pp.417-421, April 1944.

"Industrial Charcoal"*, Popular Science, The China Science Corp., Vol. 10, No. 10, pp.470-473, May, 1944.

"Bamboo and Its Engineering Uses"*, Translation, Popular Science, The China Science Corp., Vol. 10, No. 11, pp.524-527, June 1944.

"Loess at Northwestern China"*, Popular Science, The China Science Corp., Vol. 10, No. 12, pp.559-561, July 1944.

"Mysterious Photoelectric Cell"*, Popular Science, The China Science Corp., Vol. 11, No. 4, pp.136-138, November 1944.

"Formosa"*, Popular Science, The China Science Corp., Vol. 12, No. 10, pp.457-460, April 1946.

"Derris, the Insecticide"*, Popular Science, The China Corp., Vol. 13, No. 3, p.160, March 1947.

"Museum at Formosa"*, Scientific China Monthly, China Popular Publishing Corp., Vol. I, No. 6, pp.165-167, March 1947.

"Savage Tribes in Formosa"*, Popular Science, The China Science Corp., Vol 13, No. 4, pp.245-250, Vol. 13, No. 5, pp. 331-334, May 1947.

"Forestry at Aillee Mountain"*, Scientific China Monthly, China Popular Publishing Corp., Vol. II, No. 2, pp.47-50, May, 1947.

"120-km. of Suo Hwa Highway"*, Scientific China Monthly, China Popular Publishing Corp., Vol II, No. 5, pp.189-192, May, 1947.

"Mountainous Country on Tropic of Cancer"*, Popular Science, The China Science Corp., Vol. 13, No. 6, pp.378-384, June 1947.

"Water Power in Formosa, the Sun Moon Lake"*, Scientific China Monthly, China Popular Publishing Corp., Vol II, No. 3, pp.89-94, June 1947.

"Scientific Aspects in Formosa"*, Popular Science, The China Science Corp., Vol. 13, No. 8, pp.551-515, August 1947.

"Theory of Four Moments"*, Vol. 1, No. 1, Chiao Tung Engineering, The Chiao Tung University Press, 1947.

"Public Works at Formosa"*, Vol. 1, No. 7, Chiao Tung Civil Engineering, The Chiao Tung University Press, 1947.

"Gold Mine at King Ku Sai Mountain"*, co-authored with Mr. S. T. Lu, Scientific China Monthly, China Popular Publishing Corp., Vol IV, No. 1, pp.3-10, April 1948.

Discussion—"Stream Flow Variability", Proceedings, Am. Soc. Civ. Eng., Vol. 75, No. 10, pp.1508-1510, December 1949.

Discussion—"Annual Floods and the Partial Duration Flood Series", Transactions, Am. Geophys. Union, approved for publication.

"Do Climatic Variations Follow Definite Cycles?", Civil Engineering, Am. Soc. Civ. Eng., approved for publication.

Memberships of Societies

Assoc. Member, Chinese Association for the Advancement of Science. (Formerly The Science Society of China)

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